Version 1.1

MUSES PROJECT

CASE STUDY1C: MULTI-USE OF OFFSHORE WINDFARMS WITH MARINE AQUACULTURE AND FISHERIES (GERMAN NORTH SEA EEZ – NORTH SEA)

MUSES DELIVERABLE:
D3.3 - CASE STUDY IMPLEMENTATION - ANNEX 3

Maximilian F. Schupp & Bela H. Buck

Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research

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1. GEOGRAPHIC DESCRIPTION AND GEOGRAPHICAL SCOPE OF THE ANALYSIS

Germany borders two seas in which it has shared interests with many of its neighbours; the North Sea and the Baltic Sea. This analysis focuses on the specifics of the German situation in regards to the development of multi-use scenarios in the North Sea and the Baltic. Both sea basins are distinctly different from an oceanographic and ecological perspective as well as from the vested interests of a multitude of stakeholder groups.

The North Sea, a relatively young and shallow shelf sea system, is characterized by extremes. The area beyond the southern mud flats is a high-energy environment with extreme wave heights and fast currents. This poses unique technical challenges to any industry operating under these conditions. The southern mud flats of the Wadden Sea are shared by the Netherlands, Germany and Denmark and are, in large parts, protected conservation areas and declared as UNESCO World Natural Heritage sites.

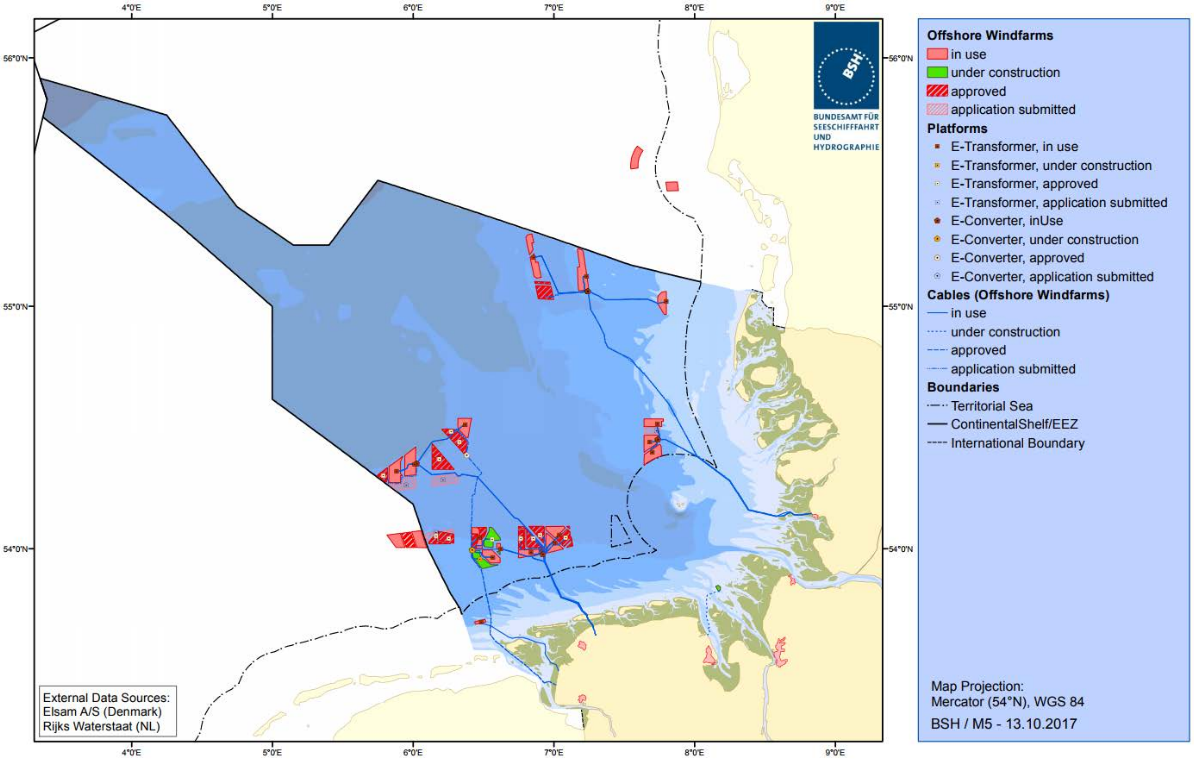

Figure 1 - Map of Offshore Windfarms in the German North Sea EEZ in use, under construction or in various phases of the permitting procedure. Source: BSH – Continental Shelf Information System (CONTIS).

This Case Study will focus on the combination of uses of fisheries and marine aquaculture individually with the expanding offshore wind industry in the North Sea. This expansion is happening mostly outside Germany’s territorial waters in the EEZ. The Case Study area encompasses therefore all those areas designated as priority areas for the development of offshore wind power generation in the German Marine Spatial Plan (MSP) (BMVBS, 2009a). The areas currently in use, under construction or in various stages of the permitting process for offshore windfarms (OWFs) are displayed in Figure 1.

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2. CURRENT CHARACTERISTICS AND TRENDS IN THE USE OF THE SEA

The German Bight is characterized by a multitude of users all vying for very limited ocean space (s. Figure 2). Germany's maritime spatial planning (MSP) process for its EEZ started in 2004 and was finished in 2009 in the form of the directive on the maritime spatial plan in the German EEZ1. During this time, stakeholders were consulted and priorities of the state and stakeholders were ascertained, resulting in a list of uses (see below). Taking into account national and international dependencies and contracts, the German EEZ was subdivided into priority areas, reservation areas, and suitable areas.

The most important current and future uses, not in order of importance or prevalence are as follows:

· **Marine traffic:** The German EEZ is part of major marine traffic transit ways going north and west as well as a route for inbound traffic serving the major ports of Hamburg, Bremerhaven, Cuxhaven and Wilhelmshaven. These dedicated shipping lanes are the most frequently used offshore waterways worldwide and constitute a major use of space causing many conflicts due to high demands for navigational security (s. Figure 2).

· **Pipelines and Cables:** Pipelines and cables form an integral part of the offshore infrastructure in the North Sea. Pipelines carry oil and natural gas while cables are used for electricity and telecommunications. This infrastructure requires special safety considerations from all users operating above and around it in order to minimise the risk of damage to vital infrastructure or causing irreparable environmental damage.

· **Offshore Wind Energy:** The offshore wind energy sector is a relatively new sector in the German EEZ but is poised to become one of the major sectors vying for space due to its exponential expansion in the recent decade. Though few offshore wind farms (OWFs) are in operation as of yet, the number as well as the applications for new OWFs are increasing (s. Figure 2). OWFs often adhere to strict safety regulations and, for the most part, constitute forbidden zones to other users.

· **Fisheries:** Fisheries are the traditional and oldest use in the case of the North Sea and still produce considerable percentages of the entire catch in EU waters. Capture fisheries produced approximately 218kt live weight (EUROSTAT database, 21.09.2017) in the German North Sea EEZ. Increasing nature protection efforts and marine traffic volume as well as the new offshore wind energy sector expansion produce conflicts concerning ocean space for this sector.

· **Nature conservation:** Marine protected areas (MPAs) constitute a major use of marine space in the German EEZ. Interests of conservationists often clash with interests of different stakeholder groups. At this point, in addition to simple nature conservation efforts, restoration projects are also being carried out to strengthen the existing populations of, or reintroduce, native species.

· **Aquaculture:** As of 2017, there is no commercial marine aquaculture activity in the German EEZ being carried. However, there has been a wealth of studies and projects investigating the suitability of candidate species and necessary engineering solutions, going as far back as the year 2000 (e. g. see Buck et al., 2017). These provide stakeholders with a solid knowledge and technology base to support future expansions in this area.

[1] Directive on the Maritime Spatial Planning in the German North Sea EEZ of the 21st of September 2009

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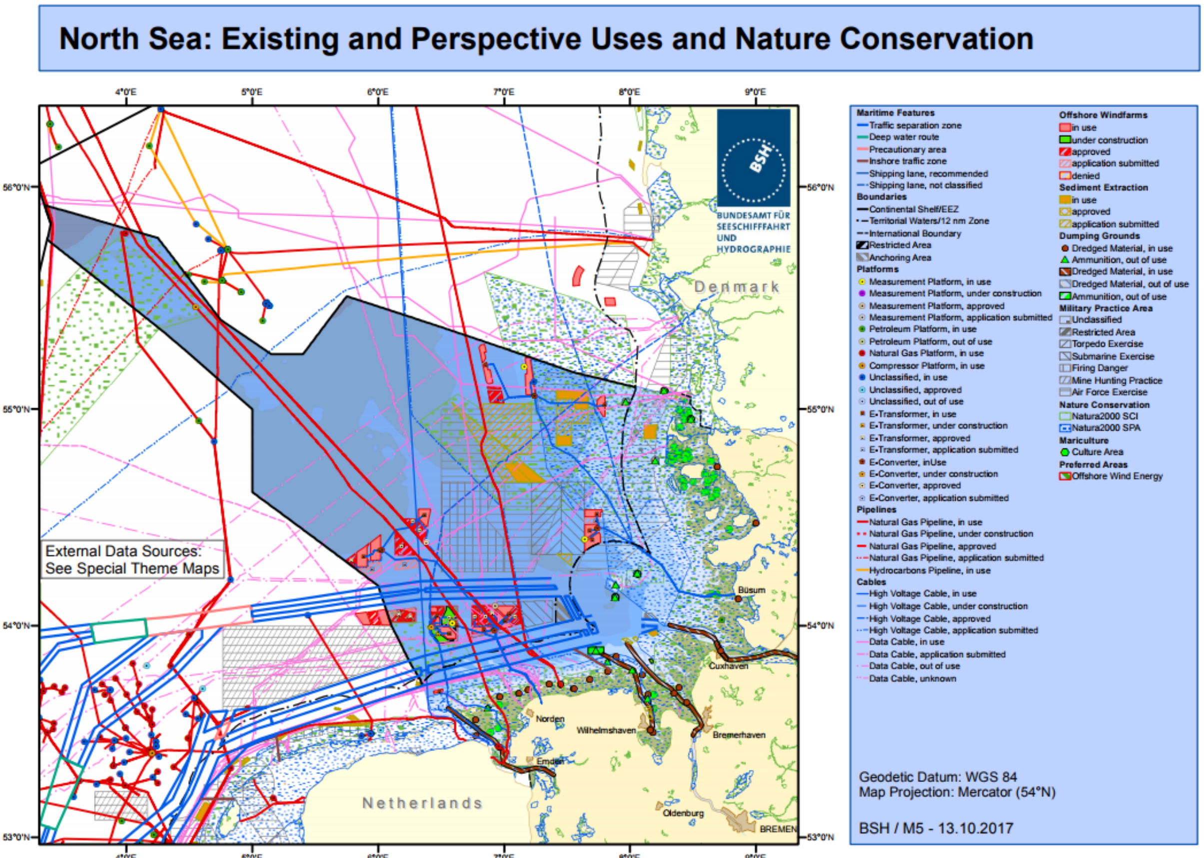

Figure 2 - Complete map of uses in the German EEZ. Source: BSH – Continental Shelf Information System (CONTIS).

True Multi-Use following the definition of the MUSES Project (see MUSES Analytical Framework) does not yet exist in the German North Sea EEZ. However, due to the increasing pressure from multiple stakeholder groups, regulators and users alike are now considering multi-use scenarios. The German MSP designates priority areas for different uses and sets up targets and principles for any offshore activity and development.

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3. MU OVERVIEW

The maritime spatial plan for the German part of the North Sea falls into two different jurisdictions. The coastal waters are managed by the federal states of Niedersachsen and Schleswig-Holstein while the EEZ falls under federal jurisdiction. This country analysis mainly focusses on multi-use scenarios in the EEZ. After completion of the public consultation process, the Federal Ministry of Transport, Building and Urban Development (BMVBS) has set forth targets and principles of the German maritime spatial plan. The spatial plan, including justification, has entered into force in September of 2009 (BMVBS, 2009b). This ordinances legal basis is the Federal Spatial Planning Act of August 1997, which was last amended in December of 2006.

The Ordinance on Spatial Planning in the German Exclusive Economic Zone and its attachments co-ordinate conflicts between new and existing uses and users as well as environmental protection targets by applying a sustainable and integrative approach. The plan designates so called priority areas in the German EEZ for different uses in which the interests of each respective use have priority over the interests of other user groups. This management approach is supported by a use-specific set of targets and principles governing the rights and responsibilities of users in their respective priority areas. Uses that are not compatible with the priority use are not permitted within this area. The application of this spatial plan falls under the jurisdiction of the Federal Maritime and Hydrographic Agency (BSH), making it one of the key stakeholders important in the decision making process surrounding the development of multi-use scenarios.

There are no economic or regulatory incentives on the national level to promote multi-use concepts at the moment. However, current regulations in the form of principles and targets technically allow for co-existence of users inside priority areas and users and regulators alike are aware of the multi-use concept.

Fisheries are a traditional use of the sea and are especially deeply rooted in coastal communities. At the same time, they do not have assigned priority areas under the German MSP due to the high spatial variability of their fishing grounds. Instead, they are awarded special considerations in the priority areas of other uses. These special considerations have to be taken into account by users and permitting authorities alike during the permitting process of OWFs according to the ordinance on offshore installations (SeeAnlV[2]). This provision, though legally binding, does not yet compel multi-use.

Marine aquaculture does not yet exist in the German EEZ, yet the MSP sets forth a framework for future development of this sector, which explicitly considers its combination with other uses like OWFs. The combination and co-location of marine aquaculture with other uses is meant to reduce the needed geographic footprint of human uses as well as create synergistic effects by e. g. reducing costs of maintenance and construction. This combination of uses can only occur under the prerequisite of ensuring navigational safety and efficiency as well as ease of operation and maintenance of OWFs. Marine aquaculture facilities have to be separately approved in accordance with the ordinance on offshore installations (SeeAnlV). No joint permitting process exists for multi-use scenarios.

[2] Directive on Structures outside Germanys territorial Waters, inside its EEZ, available at http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/Windparks/Grundlagen/SeeAnlV.pdf

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These two uses, one established and one new, offer great potential for future multi-use within OWFs. Both combinations have separately been investigated in previous research projects (see APPENDIX 2) and a wealth of information exists (see Buck and Langan (2017) for aquaculture and Stelzenmuller et al. (2016)) to support future multi-use developments.

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4. CATALOGUE OF MU DRIVERS, BARRIERS, ADDED VALUE, IMPACTS (DABI)

4.1 Combination 1: Offshore Wind & Fisheries

Fisheries have a millennia long tradition in the North Sea and socially deeply rooted in society, especially in coastal communities. Even today, North West Germany's traditional fishing harbour draws tourists who enjoy the maritime flair and fresh local products the industry provides. These traditional stakeholders now have to compete with new users moving offshore and into their traditional fishing grounds. In the German EEZ, the most space intensive and recent of those is the renewable energy industry. Following Germany's government mandated shift to renewable energy, the offshore wind industry has emerged as one of the major users of the available space in the EEZ. The installed capacity of offshore wind energy has grown almost exponentially since 2008 to over 4.5 GW (Lüers and Rehfeldt, 2016). The priority areas assigned to the industry have caused conflicts with other users, first among them the traditional fisheries sector.

The German MSP recognizes that fisheries cannot easily be restricted to certain priority areas and therefore grants fisheries special considerations, but not rights, inside other uses' priority areas. Fisheries should not hinder nor endanger construction, operation or maintenance of the OWF (BMVBS, 2009a). This has led to a state in which fishing operations, whether active or passive, are de-facto not permitted inside the security zone of OWFs.

The displacement of fishermen, often small scale or family run enterprises, from these priority areas causes them to have to move farther offshore, increasing their costs of operations to maintain the same catch levels, threatening their livelihoods.

There is, however, growing pressure from the fisheries sector about changing the status quo and this argument has recently reached the public discourse (Nicolai and Wetzel, 2017). This multi-use combination has also already been the subject of past and future research projects in Germany (e. g. COEXIST). Nonetheless, there is a clear power disparity between the two users in that, even though the fisheries sector has a long tradition in the structurally weaker coastal communities, the wind energy industry has much larger operations and profit margins while employing a significant number of people across Germany.

Based on an exchange with stakeholders and the results of previous research projects, a catalogue of factors (Table 1) was created to be analysed, discussed and scored with stakeholders.

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Table 1 Catalogue of factors (DABI) for the combination Offshore Wind Energy and Aquaculture. Factors are clustered in categories.

MU COMBINATION: Offshore Wind + Fisheries	
DRIVERS = factors promoting MU	**BARRIERS** = factors hindering MU
Category D.1 – policy drivers Factor D.1.1 Fisheries is being awarded special considerations by the German MSP inside the priority areas for Offshore Wind Farms	***Category B.1 – legal barriers*** -
Category D.2 – relations with other uses Factor D.2.1 Expansion of new uses into the available area requires spatial efficiency to maintain livelihood	***Category B.2 – administrative barriers*** Factor B.2.1 Integration into existing Health and Safety Concepts of operational OWFs is too complex and would currently have to be solved on a case by case basis
Category D.3 – economic drivers Factor D.3.1 Expansion of offshore wind power generation threatens livelihood of fisheries without multi-use development	***Category B.3 – barriers related to economic availability / risk*** Factor B.3.1 Insurance against possible damages to OWFs is prohibitively high for small scale fishing companies
Category D.4 – societal drivers -	***Category B.4 – barriers related to technical capacity*** Factor B.4.1 Determining liability in case of accidents and damage to offshore wind turbines can prove difficult and might require specialised surveillance equipment Factor B.4.2 Certain fishing methods (i. e. dredging) might damage cables connecting turbines (missing data for different depths and methods, based on precautionary principle)
Category D.5. – environmental drivers Factor D.5.1 Wind Turbines act as fish attracting devices due to the special ecosystem their foundations offer, increasing the available biomass in their immediate surroundings and creating valuable fishing grounds	***Category B.5 – barriers related to social factors*** -
	Category B.6 – barriers related to environmental factors -

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MU COMBINATION: Offshore Wind + Fisheries	
ADDED VALUES = positive effects of MU	**IMPACTS** = negative effects of MU
Category V.1 – administrative added value Factor V.1.1 Co-location with Fisheries can easily obtaining an SLO (societal license to operate) for Wind Farm developers and operators	***Category I.1 – economic impacts***
Category V.2 societal added value Factor V.2.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	***Category I.2 – societal impacts***
Category V.3 – environmental added value Factor V.3.1 Factor V.3.1 No decrease in the level of production from well managed German (and European) fisheries will lead to less imports from less well managed fishing areas across the world and not increase overfishing as well as the CO2 footprint of consumed fisheries products	***Category I.3 – environmental impacts*** Factor I.3.1 Allowing fishing inside OWFs reduces the size of the current de-facto protected areas around installations (potentially increases shipping noise, fishing pressure, pressure on benthic ecosystem, etc.)
Category V.4 – better insurance policies and risk management	***Category I.4 - technical impacts***
Category V.5 - technical added values	

4.2 Combination 2: Offshore Wind & Aquaculture

This combination differs from the combination of OWFs and fisheries in that these are two fixed uses that require significant consideration in terms of the biology of candidates, system design, management and economic potential. The installation of offshore aquaculture installations within the priority area for OWFs hold two possible scenarios in regards to connectedness: (1) the direct attachment of installations like cages or long-lines to OWF turbine foundations or (2) the co-location of aquaculture installations within the security zone of the OWF. In the case of the first scenario, considerable engineering adjustments need to be made already during the planning phase of the OWF to accommodate any extra load while maintaining acceptable safety margins, excluding this multi-use for wind farms, which have moved passed the planning stage or are already in operation. The second scenario on the other hand, creates large potential for this combination inside any wind farm already in operation or still in the planning phase. In addition to these engineering considerations, there are also multiple models of ownership or so-called modes of cooperation possible (Buck et al., 2017) further complicating stakeholder relationships. Despite these challenges, the combination of the two uses offers a large potential, which is recognized by the German MSP by explicitly advising the combination of the two uses for both users to profit from synergistic effects (BMVBS, 2009a). Such synergistic effects could for example be the sharing of high cost offshore and onshore infrastructure or the cost sharing for necessary operational expenses like the provision of active safety and emergency services.

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As with any connection of two uses, the needs of the different user groups need to be weighed against each other and a working compromise needs to be found. Under the current regulatory framework, however, OWF operators have priority over most other uses within their priority area, giving them a de-facto veto right against any development deemed hindering or even detrimental to their activities in the area. This lopsided power balance coupled with a sector wide wariness against other users possibly encroaching into their territory, makes for a difficult transition from single-user situations to true multi-use.

Based on an exchange with stakeholders and the results of previous research projects, a catalogue of factors (Table 2) was created to be analysed, discussed and scored with stakeholders.

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Table 2 Catalogue of factors (DABI) for the combination Offshore Wind Energy and Aquaculture. Factors are clustered in categories.

MU COMBINATION: Offshore Wind + Aquaculture	
DRIVERS = factors promoting MU	**BARRIERS** = factors hindering MU
Category D.1 – policy drivers Factor D.1.1 Expansion of new uses into the available area requires spatial efficiency to allow future growth of additional uses	***Category B.1 – legal barriers*** Factor B.1.1 Any activity inside an OWF must not hinder normal operations, maintenance or navigational safety inside the priority area
Category D.2 – relations with other uses Factor D.2.1 German MSP urges connection of marine aquaculture and other offshore uses in order to benefit from synergistic effects	***Category B.2 – administrative barriers*** Factor B.2.1 Licensing for multiple uses is conducted separately and offers potential for simplifications
Category D.3 – economic drivers Factor D.3.1 Increased economic potential for both users through cooperation's and sharing of resources	***Category B.3 – barriers related to economic availability / risk*** Factor B.3.1 Moving aquaculture offshore requires special engineering solutions and makes day-to-day operations more expensive Factor B.3.2 Insurance against possible damages to OWFs is prohibitively high for small scale aquaculture companies
Category D.4 – societal drivers -	***Category B.4 – barriers related to technical capacity*** Factor B.4.1 Connection of aquaculture systems to existing OWFs is not possible unless it was designed for the increased load Factor B.4.2 Operations within OWFs would require a degree of integration into the Health & Safety Concept of the operator which is often not easily accessible
Category D.5. – environmental drivers -	***Category B.5 – barriers related to social factors***
	Category B.6 – barriers related to environmental factors Factor B.6.1 Opposition to aquaculture (whether fed, extractive or IMTA) in German waters

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MU COMBINATION: Offshore Wind + Aquaculture	
ADDED VALUES = positive effects of MU	**IMPACTS** = negative effects of MU
Category V.1 – administrative added value Factor V.1.1 Co-location with Fisheries can assist the prospect of obtaining an SLO (societal license to operate) for Wind Farm developers and operators	***Category I.1 – economic impacts***
Category V.2 – economic added value Factor V.2.1 Possible lowering of operational costs for all involved actors through sharing of resources (e. g. vessels, ports, etc.) and integration and cost sharing of health and safety concepts	***Category I.2 – societal impacts***
Category V.3 – environmental added value Factor V.3.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	***Category I.3 – environmental impacts*** Factor I.3.1 If aquaculture is not well managed according to BMP (best management practice), BAT (best available technology) and BEP (best environmental practice), it can have negative impacts on the marine environment (e. g. eutrophication, spread of disease or impact of escapees on natural populations)
Category V.4 – better insurance policies and risk management	***Category I.4 - technical impacts***
Category V.5 - technical added values	

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5. RESULTS OF DABI SCORING: ANALYSIS OF MU POTENTIAL AND MU EFFECT

The pre-prepared catalogue of factors (drivers, barriers, added values and impacts) of multi-use development were presented to and discussed with a selection of key stakeholders during semi-structured interviews (see Chapter 7.1). Factors were scored by stakeholders according to the MUSES WP3 Methodology. Drivers and added values were scored between 0 and +3 based on stakeholder's subjective view and experience, while barriers and negative impacts were scored between 0 and -3. If a stakeholder did not agree with a factor or had no knowledge about it, the factor received no score (NA). During the analysis presented in Tables 3-6, average factor scores were averaged within categories and within their respective type (i. e. driver, barrier, etc.) to provide an overview. An overall multi-use potential and overall multi-use effect score were calculated for each combination by adding positive and negative averages of drivers and barriers and added values and impacts, respectively.

This methodology only serves to rudimentarily compare stakeholders strictly subjective perception of the individual drivers, barriers, added values and impacts of a given multi-use scenarios. A substantially higher sample of stakeholder is necessary to draw conclusions about a whole communities perceptions around multi-use. This case study, however, focused on engaging key stakeholders in specific industries and important regulatory bodies identified as key knowledge holders or decision makers. This quality over quantity approach served to identify key steps forward in multi-use development.

5.1 Combination 1: Offshore Wind & Fisheries

The most prominent driver for the multi-use of OWFs and fishing grounds, according to stakeholder perceptions, was the need for spatial efficiency in order to maintain the livelihoods of established users, i. e. fishermen (see Table 3). The barrier perceived as the most relevant on the other side stemmed from the perceived risk of fishing operations within the windfarm and the resulting need for prohibitively high insurance costs. The next largest barrier was the need to integrate other users into established health, safety and emergency concepts while they are operating within the windfarm. This can prove to be problematic since those concepts are different from operator to operator and integration could only be attempted on a case by case basis at the current point. The overall multi-use potential for this combination comes out to +0.50.

The highest scoring added value is perceived to be for society due to the fact that increased spatial efficiency will enable MSP authorities to keep other areas mostly clear of other uses and reserved for future uses. Those potential future uses (e. g. carbon sequestration or hydrogen generation) could provide a large benefit to society and their possible spatial needs could be met by attaining greater spatial efficiency right now. The only scored negative impact of this multi-use combination is that with the permitting of fisheries inside offshore windfarms the de-facto fishing free zones and any possible environmental benefit they might possess will be lost. It is, however, important to note here that this potential environmental benefit of a fishing free zone inside windfarms is not recognised or stipulated in the relevant laws. The cumulative overall multi-use effect out of these factors is -0.17.

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Table 3 Catalogue of factors for the combination Offshore Wind Energy and Fisheries scored by stakeholders. Average score is calculated by averaging scores given by all the stakeholders for the same factor. Factors are listed from +3 to 0 for drivers and added values, and from -3 to 0 for barriers and impacts. Factors are listed from highest average score to lowest.

MU COMBINATION: Offshore Wind + Fisheries					
DRIVERS = factors promoting MU			**BARRIERS** = factors hindering MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor D.2.1 Expansion of new uses into the available area requires spatial efficiency to maintain livelihoods	D.2 Relation with other users	2,5 (n = 3)	Factor B.3.1 Insurance against possible damages to OWFs is prohibitively high for small scale fishing companies	B.3 barriers related to economic availability / risk	-3,0 (n = 1)
Factor D.1.1 Fisheries is being awarded special considerations by the German MSP inside the priority areas for Offshore Wind Farms	D.1 Policy drivers	No score (n = 0)	Factor B.2.1 Integration into existing Health and Safety Concepts of operational OWFs is too complex and would currently have to be solved on a case by case basis	B.2 administrative barriers	-1,0 (n = 1)
Factor D.5.1 Wind Turbines act as Fish attracting devices due to the special ecosystem their foundations offer, increasing the available biomass in their immediate surroundings and creating valuable fishing grounds	D.5 Environmental driver	No score (n = 0)	Factor B.4.1 Determining liability in case of accidents and damage to offshore wind turbines can proof difficult and might require specialised surveillance equipment	B.4 barriers related to technical capacity	0,0 (n = 3)
			Factor B.4.2 Certain fishing methods (i. e. dredging) might damage cables connecting turbines (missing data for different depths and methods, based on precautionary principle)	B.4 barriers related to technical capacity	No score (n = 0)
DRIVERS average score		**+2,50**	**BARRIERS average score**		**-2,00**
		MU POTENTIAL	**+0,50**		

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ADDED VALUES = positive effects of MU			IMPACTS = negative effects of MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor V.2.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	V.2 Societal added values	3,0 (n = 1)	Factor I.3.1 Allowing fishing inside OWFs reduces the size of the current de-facto protected areas around installations (potentially increases shipping noise, fishing pressure, pressure on benthic ecosystem, etc.)	I.3 environmental impacts	-2,0 (n = 1)
Factor V.1.1 Co-location with Fisheries can ease obtaining an SLO (societal license to operate) for Wind Farm developers and operators	V.1 Admistrative added values	1,5 (n = 3)			
Factor V.3.1 No decrease in the level of production from well managed German (and European) fisheries will lead to less imports from less well managed fishing areas across the world and not increase overfishing as well as the CO2 footprint of consumed fisheries products	V.3 environmental added values	1,0 (n = 1)			
ADDED VALUES average score		**+1,83**	**IMPACTS average score**		**-2,00**
		MU OVERALL EFFECT	**-0,17**		

Table 4 presents the overall highest scoring categories for the drivers, barriers, added values and impacts for this combinations.

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Table 4 Average category score for all drivers, barriers, added values and impacts of the combination Offshore Wind Energy and Fisheries. Categories are listed from +3 to 0 for drivers and added values, and from -3 to 0 for barriers and impacts. Categories are sorted by highest/lowest average score. Only categories with scored drivers are listed.

MU COMBINATION: Offshore Wind + Fisheries			
DRIVERS = factors promoting MU		**BARRIERS** = factors hindering MU	
Category	**Average score**	**Category**	**Average score**
D.2 relation to other uses	2,5 (n = 3)	B.3 barriers related to economic availability / risk	-3,0 (n = 1)
		B.2 administrative	-1,0 (n = 1)
		B.4 barriers related to technical capacity	0,0 (n = 3)
ADDED VALUES = positive effects of MU		**IMPACTS** = negative effects of MU	
Category	**Average score**	**Category**	**Average score**
V.2 societal added values	3,0 (n = 1)	I.3 environmental impacts	-2,0 (n = 1)
V.1 administrative added values	1,5 (n = 3)		
V.3 environmental added values	1,0 (n = 1)		

5.2 Combination 2: Offshore Wind & Aquaculture

The driver for the combination of OWFs and marine aquaculture that scored the highest by stakeholders was the need for spatial efficiency in Germany's comparatively cramped EEZ. On the other side, the highest scored barriers were related to the technical challenges of attaching culture systems to existing windfarms, resulting in the need to either plan windfarm and aquaculture use at the same time or build culture systems that are completely detached from the windfarm structures. Other barriers related to safety concerns for the higher value OWF installations by the aquaculture operators or the legal hurdle that is the separate permitting procedures for uses. The overall multi-use potential out of all scored drivers and barriers is +0.25.

The highest scored added values were the possibility of decreasing the human footprint in the German EEZ and the economic aspect of lowered operational costs for both users in the case of integration of activities. The only scored negative impact this combination was perceived to have was the possible negative impact of aquaculture systems that are not managed according to BMP (best management practice), BAT (best available technology) and BEP (best environmental practice). The overall multi-use effect for this combination comes out to +0.50.

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Table 5 Catalogue of factors for the combination Offshore Wind Energy and Aquaculture scored by stakeholders. Average score is calculated averaging scores given by all the stakeholders for the same factor. Factors are listed from +3 to 0 for drivers and added values, and from -3 to 0 for barriers and impacts. Factors are listed from highest average score to lowest.

MU COMBINATION: Offshore Wind + Aquaculture					
DRIVERS = factors promoting MU			**BARRIERS** = factors hindering MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor D.1.1 Expansion of new uses into the available area requires spatial efficiency to allow future growth of additional uses	D.1 Policy drivers	2,5 (n = 3)	Factor B.4.1 Connection of aquaculture systems to existing OWFs is not possible unless it was designed for the increased load	B.4 barriers related to technical capacity	-3,0 (n = 2)
Factor D.2.1 German MSP urges connection of marine aquaculture and other offshore uses in order to benefit from synergistic effects	D.2 Relation with other users	No score (n = 0)	Factor B.3.2 Insurance against possible damages to OWFs is prohibitively high for small scale fishing companies	B.3 barriers related to economic availability / risk	-3,0 (n = 1)
Factor D.3.1 Increased economic potential for both users through cooperation's and sharing of resources	D.3 Economic drivers	No score (n = 0)	Factor B.3.1 Moving aquaculture offshore requires special engineering solutions and makes day-to-day operations more expensive	B.3 barriers related to economic availability / risk	-2,0 (n = 1)
			Factor B.2.1 Licensing for multiple uses is conducted separately and offers potential for simplifications	B.2 administrative barriers	-1,0 (n = 1)
			Factor B.1.1 Any activity inside OWF must not hinder normal operations, maintenance or navigational safety inside the priority area	B.1 legal barriers	No score (n = 0)
			Factor B.4.2 Operations within OWFs would require a degree of integration into the Health & Safety Concept of the operator which is often not easily accessible	B.4 barriers related to technical capacity	No score (n = 0)
			Factor B.6.1 Opposition to aquaculture (whether fed, extractive or IMTA) in German waters	B.6 barriers related to environmental factors	No score (n = 0)
DRIVERS average score		**+2,5**	**BARRIERS average score**		**-2,25**
		MU POTENTIAL	**+0,25**		

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ADDED VALUES = positive effects of MU			IMPACTS = negative effects of MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor V.3.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	V.3 environmental added values	3,0 (n = 1)	Factor I.3.1 If aquaculture is not well managed according to BMP (best management practice), BAT (best available technology) and BEP (best environmental practice), it can have negative impacts on the marine environment (e. g. eutrophication, spread of disease or impact of escapees on natural populations)	I.3 environmental impacts	-1,5 (n = 2)
Factor V.2.1 Possible lowering of operational costs for all involved actors through sharing of resources (e. g. vessels, ports, etc.) and integration and cost sharing of health and safety concepts	V.2 economical added values	1,5 (n = 2)			
Factor V.1.1 Co-location with Fisheries can ease obtaining an SLO (societal license to operate) for Wind Farm developers and operators	V.1 Admistrative added values	1,5 (n = 3)			
ADDED VALUES average score		**+2,00**	**IMPACTS average score**		**-1,5**
		MU OVERALL EFFECT	**+0,50**		

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Table 6 presents the overall highest scoring categories for the drivers, barriers, added values and impacts for this combinations.

Table 6 Average category score for all drivers, barriers, added values and impacts of the combination Offshore Wind Energy and Aquaculture. Categories are listed from +3 to 0 for drivers and added values, and from -3 to 0 for barriers and impacts. Categories are sorted by highest/lowest average score. Only categories with scored drivers are listed.

MU COMBINATION: Offshore Wind + Aquaculture			
DRIVERS = factors promoting MU		**BARRIERS** = factors hindering MU	
Category	**Average score**	**Category**	**Average score**
D.1 policy drivers	2,5 (n = 1)	B.4 barriers related to technical capacity	-3,0 (n = 1)
		B.3 barriers related to economic availability / risk	-2,5 (n = 2)
		B.2 administrative barriers	-1,0 (n = 1)
ADDED VALUES = positive effects of MU		**IMPACTS** = negative effects of MU	
Category	**Average score**	**Category**	**Average score**
V.3 environmental added values	3,0 (n = 1)	I.3 environmental impacts	-2,0 (n = 1)
V.2 economical added values	1,5 (n = 1)		
V.1 administrative added values	1,5 (n = 1)		

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6. FOCUS AREAS ANALYSIS

The Focus Area Analysis is a summary and evaluation of the case study results according to common conceptual categories. These categories are shared between all MUSES case studies. The answers to the Key Evaluation Questions of each of the three focus areas have been prepared by the case study leader and reviewed and commented by a subset of three stakeholders (regulators and industry representatives), resulting in the following answers. Answers encompass Germany's multi-use situation in regards to both promising combinations examined in detail in this case study.

6.1 Focus-Area-1 "Addressing Multi-Use"

1. Is it possible to establish / widen / strengthen MU in the case study area? (Y/N) For which MU combination in particular? What needs would MU satisfy?
    - The German North Sea EEZ offers potential for different multi-use combinations. The most immediate economically relevant amongst them are combinations of established or new uses (fisheries or marine aquaculture) with the expanding offshore wind power generation. A large base of scientific knowledge exists for both multi-use combinations in question (i. e. Buck and Langan (2017) and Stelzenmüller et al. (2013)). MU should seek to create synergies between different users, saving costs and manpower while operating offshore, as well as increase the economic potential of a given area by using the available space in an efficient manner. Possible other uses are ecotourism in OWFs or the combination of restoration activities with OWFs.

2. Is space availability an issue for MU development / strengthening in the case study area at present? (Y/N) Will space availability become an issue for your area in the future? (Y/N) For what elements is / could space availability become an issue?
    - Space availability is already an issue in the German North Sea EEZ. It hosts the busiest waterways worldwide as well as a multitude of other uses and users. Particularly regarding the combination of OWFs and fisheries, either active or passive, the availability of space for each use is a driving factor. The combination of OWFs with marine aquaculture, however, is more driven by synergies created by the co-location of the two uses. Priority areas for most uses are allocated according to the German MSP (AWZ Nordsee-ROV[3]), while e. g. fisheries are only awarded special considerations inside other uses priority areas. Moreover, potential new uses like marine aquaculture, though explicitly mentioned in the MSP, have no allocated areas under the current system.

3. Are there MUs combinations and potentials that will share the same resources but in different times (e. g. reuse of an infrastructure after the end of its first life and original scope)? (Y/N) What are they?
    - The two MU combinations identified as the most promising future combinations (OW&AQ and OW&Fisheries) will use resources in the same time-frame. An additional combination that is plausible in the future is the combination of offshore wind turbines with environmental protection. This combination could potentially allow for a re-use of

[3] MSP for the German North Sea EEZ. Available at: http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/index.jsp

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certain offshore structures (i. e. as artificial reefs) in order to create an added benefit for the local ecosystem. There is, however, currently no legal framework under which this multi-use could take place as German marine spatial planning works on the premise that all structures being erected in the marine realm by humans will be removed at the end of their designated life span.

4. What would be the most important resources to be shared between uses (infrastructures, services, personnel, etc.)?
    - While the combination of offshore wind energy generation with fisheries could create synergies by integrating emergency systems and protocols as well as monitoring systems, the combination of offshore wind energy generation and marine aquaculture could benefit from a closer integration. Next to the previously mentioned sharing of monitoring and emergency services, the sharing of vessels, as well as offshore infrastructure and potentially personnel, could lead to a substantial benefit for users by reducing costs of operation on both sides.

5. Are existing and/or potential MUs taken into account within the existing or under development Maritime Spatial Plans? (Y/N)
    - The German MSP (AWZ-North Sea ROV) works on the principle of assigning priority areas to most uses to minimize conflict and optimize the co-existence of multiple users in a confined and crowded sea space. The potential multi-use of offshore wind priority areas by fisheries or marine aquaculture is mentioned in the relevant MSP documents. However, fisheries are, as a geographically wide ranging use, not bound to specific priority areas, but rather are awarded so called special considerations but not rights inside priority areas of other uses. Marine aquaculture is a completely new use in the German EEZ and as such, only scantly appears in the relevant documents. The MSP however, recognizes the potential for synergies for the combination of other offshore uses like offshore wind power generation and loosely promotes such combinations.

6. How are MUs connected or related to land-based activities?
    - Marine aquaculture relies heavily on the continuous provision of services and maintenance from land-based facilities in the closest harbour. It follows therefore that the distance to the nearest service harbour has to be as short as possible or the installations have to have a higher degree of autonomy (e. g. smart systems). Fisheries have a similar but less acute need for closeness of their activities to their harbours. Any increase in the necessary travel distance decreases the bottom line of the business.

7. Is the needed knowledge and technology for MU development/strengthening in the case study area already available? (Y/N) What is the level of maturity of available knowledge? What is the level of readiness of available technology? Are there still research needs? (Y/N)
    - The technology for the combination of both fisheries and marine aquaculture with offshore wind energy generation for the most part already exists in the case study area. Technologies, site selection tools, as well as management and permitting guidelines for the integration of marine aquaculture into offshore wind parks, have been in development since the early 2000s and have been tested as prototypes under offshore

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conditions. A market-ready showcase installation, however, is still missing and is the next step in developing and showcasing the best available technology. Technological Readiness Levels (TRLs) range from 4 to 6.
Fisheries on the other hand, as a long established use, benefits from a large array of tested methods and technology. The lack in this case is the need for operational multi-use scenarios showcasing safety of protocols and technologies to other key stakeholders.

8. What action(s) would you recommend to develop / widen / strengthen MU in the case study area? What actor(s) do you see particularly important to develop / widen / strengthen MU in the case study area?
    - Both combinations investigated in this case study require an operational, market size showcase installation/instance of multi-use. These showcases for fisheries inside OWFs as well as marine aquaculture need to focus on demonstrating the safety of the combination along with all synergies created by them. The results of such showcases need to be openly communicated to relevant stakeholders to decrease opposition and remove barriers.

6.2 Focus-Area-2 "Boosting Maritime Blue Economy"

1. Do you see added values for society and economy at large and/or for local communities of developing / widening / strengthening MU in the case study area? (Y/N). What are the most important ones?
    - Fisheries and aquaculture both produce marine products for either human consumption or other uses. There is a large worldwide demand that industries are trying to meet. Different countries and industries have, however, widely differing environmental standards that they adhere to. Their products therefore come with differing environmental footprints attached to them. Increasing or sustaining the local production of fisheries and aquaculture products according to best environmental practice (BEP), best management practice (BMP) and best available technology (BAT), as defined by the FAO, therefore could decrease the overall ecological and carbon footprint created by our societal demands.
    In addition to the wider ecological argument, a more local economic argument can be made as well. Coastal communities generally represent some of the structurally weakest communities in Germany. Both sustained local fisheries as well as the emergence of marine aquaculture as a new engine for growth represent a significant added value for local communities around the harbour servicing offshore installations.

2. Is it possible to quantify the socio-economic benefits related to MUs and how they (could) contribute to the sea economy at local and regional/national scale? (Y/N) What tools, knowledge, experiences are available?
    - The socio-economic impact of both multi-use combinations can be assessed even though they are not yet realized. For fisheries, detailed data about company size, vessel sizes, landed catch, fishing area etc. is already collected. These data could be used in a multi-

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use scenario to make a concrete socio-economic case for the combination of the two uses.
Aquaculture on the other hand is a completely un-established use in the German EEZ and hence no standardized procedures for data collection exist as of yet. Parallels, however, can be drawn between the developments of similar sectors in other countries (e. g. Norway).

3. Would MU development / strengthening be an opportunity for job creation and / or job requalification in your area? (Y/N)
   - The multi-use combination of offshore wind energy generation and fisheries would, in the first instance, act to preserve jobs in the local fishing industry by allowing for further operation within areas assigned to other uses.
     The development of a marine aquaculture sector, however, can serve to create new jobs or offer the potential for retraining for workers from land-based aquaculture sectors or other offshore industries (i. e. oil & gas, offshore wind or fisheries). Retraining notwithstanding, new and emerging offshore industries require a high level of specialisation and will also have to rely on newly trained specialised staff.

4. Do you see possible elements of attractiveness for investors in developing / widening / strengthening MU in the case study area? (Y/N) What are these elements?
   - Especially the combination of marine aquaculture and offshore wind parks offers an opportunity for investors to produce high quality products close to many of the biggest European markets. Not only the combination but rather the integration of the two uses and the resulting synergies could lead to a reduction of traditionally high offshore operating costs which could draw investors to these multi-use scenarios. The arrival of new offshore industries like marine aquaculture inside OWFs is also attractive to related industries engaged in the manufacturing of necessary equipment and installations.

5. What are possible investors interested in developing / widening / strengthening MU in the case study area?
   - Possible investors potentially interested in multi-use scenarios of fisheries or aquaculture inside offshore wind parks would be the representatives of each industry. Possible investors in marine aquaculture and especially offshore marine aquaculture need to be large corporate investors to contend with the high initial investment costs. As there is no established offshore marine aquaculture industry in Germany as of yet, such large scale investors could possibly come from foreign markets, interested in expanding their production capacity in other areas, provided the surrounding framework allows for such investments to be made.

6. Is there sufficient dialogue between the stakeholder sectors for developing / widening / strengthening MU? (Y/N) Would dialogue facilitation be an asset? (Y/N)
   - Dialogue between some actors is already established for both combinations in the form of either professional networks or passed joint research projects on the topic. However, this dialogue needs to grow substantially and be extended to involve all key stakeholders. The content of this dialogue needs to be the exchange of the best available

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information as well as the communication of possible synergies and alleviation of specific concerns.

7. In order to promote MU development / strengthening in the case study area:
   - Would the availability of a vision/strategy (e. g. at national or sub-regional level) be helpful? (Y/N)
   - Would a feasibility study including evaluation of alternative scenarios be helpful? (Y/N)
   - Would detailed projects on already identified simulations be useful? (Y/N)
   - Do you see other enablers?
     - No multi-use development or investment into such developments can take place without the proper framework around it. To such an end, a common vision/strategy for multi-use development and operation between policy makers, regulators as well as all involved users is indispensable. To further this common strategy, the best available knowledge needs to be attained and distributed between all relevant stakeholders and decision makers. Multiple research projects assessing both combinations have already been carried out and have produced large amounts of data from economics to ecological impacts. This data needs to be communicated as well as underscored by a final, market ready prototype study addressing all concerns previously unaddressed.

6.3 Focus-Area-3 "Improving environmental compatibility"

1. What are / would be the environmental added values (= positive environmental impacts) of developing / widening / strengthening MU in the case study area?
   - The most immediate environmental added value from developing multi-use for either combination is the sustainable production of aquatic organisms as opposed to the exportation of the ecological impacts associated with German societal demand for sea food to other countries. The increased spatial efficiency and therefore decreased overall use of space for human activities also offers the potential to reserve more marine areas for conservation purposes, therefore creating an ecological benefit in other areas.

2. Which tools (conceptual, operational) are used or should be further developed and used to better estimate environmental impacts and benefits of MU?
   - Environmental impact assessment (EIA) is in use in Germany and offers an operational and established way to assess the environmental impacts of human activities. Germany benefits from an early adoption and implementation of EIA procedures in its offshore permitting process. The Standard for Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK4[4]), for example, has been in use for a number of years and has, in various forms, been adapted by other countries subsequently.
     What Germany is lacking, however, are mechanisms and frameworks to assess (1) the cumulative impacts or benefits of multi-use scenarios and (2) the socio-economic benefits and impacts.

[4] Standard for the Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment, available at http://www.bsh.de/de/Produkte/Buecher/Standard/index.jsp

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3. Is saving free sea space for nature conservation a driver for MU in the case study area? (Y/N) Is there evidences about the present and future benefits of reserving free sea space? (Y/N) What are they?
    - Not expanding human activities past the minimum area necessary and exercising spatial efficiency in planning and operations can have two main benefits: (1) the area left void of other human uses can act as a de-facto protected area, providing a benefit to the whole ecosystem while also (2) reserving ocean space for the use of currently far flung future uses such as carbon sequestration, hydrogen generation or others.

4. What practical actions would you undertake to link MU development / widening / strengthening to improved environmental compatibility of maritime activities?
    - In order to ensure that multi-use improves the environmental compatibility of maritime activities, a set of principles for the future development of such scenarios is required. These principles have to lay the foundation for multi-use as a new, sustainable and long-term solution to meet society's demands while conserving natural resources. These principles of multi-use development have to be created jointly between all relevant stakeholders and adopted by decision makers and actors alike.

5. Are there win-win solutions triggering both socio-economic development and environmental protection already available for the case study area that MU should take up? (Y/N) What are they?
    - Environmental protection can serve to protect ecosystem goods and services, therefore passively positively impacting the socio-economic situation of communities directly depended on those goods and services. There are, however, no immediate socio-economic and environmental win-win solutions for the two multi-use combinations analysed in this case study. Furthermore, a win-win solution needs constant assessment and reinforcement in order to monitor and maintain its positive effect. The analysed scenarios offer the potential of a socio-economic win and environmental no-lose scenario in that the environment will not be harmed by well managed acitivies.

6. Is the environmentally friendly knowledge / technology for MU development/strengthening in the case study area available? (Y/N) Which is the level of readiness of available solutions? Are there still research needs on blue/green technologies for MU? (Y/N)
    - Both analysed combinations can draw from a large cache of environmentally friendly knowledge and technology. This encompasses e. g. proven fishery methods and management approaches as well as marine aquaculture management approaches. The available technologies and practices are all either tested at prototype level or already adopted by the sector and in use. The research needs of both multi-use combinations at this point are not blue/green technologies but rather the seamless integration of different uses while minimising conflicts and maximising synergies. Management approaches are required more immediately.

7. Would it be possible to promote MU through SEA/EIA procedures? (Y/N) What modifications would you suggest at your national / local level to promote MU through SEA/EIA procedures?

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- There is a need for more complete assessments in regards to the drawbacks and benefits of multi-use to guide policy makers. A national approach to the SEA (strategic environmental assessment) underscored by the relevant EIAs could lead to policy makers, regulators and general actors who are better informed and better able to make decision according the best available knowledge.

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7. STAKEHOLDER ENGAGEMENT AND LOCAL STAKEHOLDER PROFILES

7.1 Stakeholder Engagement Methodology

7.1.1 MU Combination: fisheries and offshore wind

Based on a complete stakeholder mapping conducted at the beginning of the case study, as well as scanning of previous project results, project partners and feedback from stakeholders, four key stakeholders were identified for personal interviews (Table 7). Key stakeholders were chosen in such a way that for the involvement of one regulator and one industry spokesperson for each of the two main combinations. Industry representatives were active in industry wide cluster associations and all had close ties to and personal experiences in the industry to be able to speak for more than one singular actor.

All stakeholders responded positively to interview requests, in part due to previous involvement in joint projects and pre-existing relationships, and agreed to freely share information, indicating so in the signed MUSES consent forms. Consent forms and interview sheets are stored locally. To streamline the interview procedure, semi-structured interviews of approximately two hours in length were conducted using an interview guide (APPENDIX 3) created based on the sheets provided in the MUSES WP3 Methodology.

Table 7 – Overview of key stakeholders engaged during the case study process.

Stakeholder (Name of organization)	Short description (role and competence	Relevance for MU	Selection method (i. e. nominated by other SH, identified in previous project or in Pool WS, other)	Indicate the form of interview (i. e. tel., personal talk, other-specify)	In case interview was conducted please describe here why
Stiftung Offshore Wind (StOW)	Industry wide cluster association that assists the German OW-industry in any capacity from consulting to planning	Works closely with most major developers in the German EEZ and has top down view of the entire process from permitting, to planning to operation	Identified in previous project	Personal semi-structured interview (ca. 2 hours)	Stakeholder was able to cover a wide range of DABIs from multiple viewpoints as they have a cross-industry perspective
Deutscher Fischerei Verband (DFV)	Industry wide cluster association that acts as network and special interest group for the German	Represents established interests of the German fisheries sector	Identified in previous project	Personal semi-structured interview (ca. 2 hours)	Stakeholder was able to cover a wide range of DABIs from multiple viewpoints as they have a cross-industry perspective

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	fisheries industry				
Bundesamt für Seeschifffahrt und Hydrographie (BSH)	Federal MSP authority in German EEZ, tasked with permitting	German MSP Regulatory Agency	Identified in previous project	Personal semi-structured interview (ca. 2 hours)	Main MSP Authority in German Waters so vital to MUSES efforts in Germany
Bundesverband Aquakultur (BVAQ)	Industry wide cluster association that acts as network and special interest group for the German aquaculture industry	Represents interests of Aquaculture advocates from industry and research	Identified in previous project/Member of	Continuous feedback into the MUSES project	Stakeholder was able to cover a wide range of DABIs from multiple viewpoints as they have a cross-industry perspective

Germany's situation in regards to multi-use is special in so far as a lot of research on both analysed combinations has already been conducted, often involving many stakeholders. These projects have all organised workshops with most of the relevant stakeholders, resulting in a very informed stakeholder base. Instead of repeating the approach of previous projects and engaging the same stakeholder again, this case study explicitly focused on a smaller subsample of key stakeholders in the specific industries and important regulatory bodies identified as key knowledge holders or decision makers. This quality over quantity approach served to identify key steps forward in multi-use development, while not over-engaging a broad mass of stakeholders.

7.2 Local Stakeholder Profiles

7.1.2 MU Combination: fisheries and offshore wind

The following stakeholder profiles have been prepared based on the experiences and desk analysis of the case study leader and represent a subjective view of the leanings and opinions of the large stakeholder groups (fisheries, offshore wind energy, aquaculture and cross-sector regulators) most relevant to the Germany case study. A summary of all attributes for all Stakeholder Groups in regards to multi-use is presented in Table 8. The groups are each described in regards to the following attributes towards the specific multi-use combination:

- Overall interest in MU
- Overall attitude towards MU
- Geographical scale at which certain stakeholder has the power
- Organisation of stakeholders
- Type of power
- Level of Power

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7.3.1 MU Combination: fisheries and offshore wind

OVERALL INTEREST IN MU:

Fisheries Industry: The fisheries sector as a whole is proactive towards multi-use projects. Key stakeholders previously participated in projects exploring the feasibility of multi-use, analysing barriers and providing approaches for future multi-use.

Offshore Wind Industry: The offshore wind industry as a whole has a low interest in multi-use of any kind unless there are clear added values and no risks involved. Certain key companies and associations, however, are interested in multi-use as a future use concept and have been partners in past research projects.

Cross-sector: Regulatory bodies are open to fisheries in connection with the offshore wind energy as a multi-use. Regulators have been open to inquiries as well as project participation.

OVERALL ATTITUDE TOWARDS MU:

Fisheries Industry: The fisheries sector as a whole is a positive driving force behind the development of this multi-use combination. The introduction of the offshore wind industry as an established user in the German North Sea EEZ and has had their available space for fishing activities reduced, especially in the EEZ areas closest to the shore. Driving multi-use concepts forward serves their own economic interests.

Offshore Wind Industry: The overall attitude of the offshore wind industry in regards to multi-use in any use combination is cautious. Under the German MSP for the EEZ, they have priority rights over other users inside their assigned priority areas. These protect their construction, operation and maintenance activities from other users. Most stakeholders see no need to jeopardize the security these rights guarantee them. These opposed actors possess an absolute veto-right against all activities inside their priority areas and use it to impose barriers. Some key stakeholders in the industry, however, are open to alternative use concepts and have participated in past projects in order to identify the approaches.

Cross-sector: Regulatory bodies are open to fisheries in connection with offshore wind energy as a multi-use. Regulators have been open to inquiries as well as project participation.

GEOGRAPHICAL SCALE AT WHICH CERTAIN STAKEHOLDER HAS THE POWER:

Fisheries Industry: The German fishing sector is represented by associations on a state and federal level. Representation or lobbying on a European level can only happen by coordination with associations from other countries.

Offshore Wind Industry: Key offshore wind stakeholders, whether planners or operators, are almost exclusively part of multi-national energy providers with a sea basin or EU perspective.

Cross-sector: Relevant cross-sector authorities for this multi-use combination operate on the regional to national level.

ORGANISATION OF STAKEHOLDERS:

Fisheries Industry: The German fisheries sector is made up of a large number of small, often family run, enterprises. A few larger conglomerates exists. The sector is being represented on a national

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level by the German Fisheries Association (DFV).
Offshore Wind Industry: The offshore wind industry is dominated by a low number of mostly multi-national energy corporations. They jointly support multiple associations and lobby groups to advance their interests.
Cross-sector: Cross-sector authorities are organised at the federal-state (coastal states) and federal level.

TYPE OF POWER:

Fisheries Industry: The power of the German fisheries sector lays in influencing decision makers on the national and international level. They have no direct power to advance this multi-use combination with OWFs.
Offshore Wind Industry: The offshore wind industry has greater influencing power than the second user, fisheries in this case, due to their larger operations. The lead corporations are multi-national companies operating at a sea basin or EU wide level and provide thousands of high paid jobs in the technology sector. Further, they have special absolute rights within their assigned priority areas over other uses and users.
Cross-sector: Relevant cross-sector authorities have direct power to control and make decisions within their mandated purview. They are immediately responsible for applying regulations and manage their jurisdictions accordingly. Apart from that they have the power to directly influence the decision making process.

LEVEL OF POWER:

Fisheries Industry: The level of power of the German fisheries industry is comparably low in this combination. The fisheries sector, though it has a longer tradition, does not hold the same type of power as the energy sector. It is therefore the weaker user in this multi-use scenario.
Offshore Wind Industry: The offshore wind industry has a larger influencing power than the second user, fisheries in this case, due to their larger operations. The lead corporations are multi-national companies operating at a sea basin or EU wide level and provide thousands of high paid jobs in the technology sector.
Cross-sector: The power of the cross-sector authorities is strong as it is absolute within their mandated purview. They need to be included in any communication process regarding multi-use.

7.3.2 MU COMBINATION: AQUACULTURE & OFFSHORE WIND

OVERALL INTEREST IN MU:

Aquaculture Industry: There is no offshore aquaculture industry active in the German North Sea EEZ as of yet. The strong interest in the offshore aquaculture sector in Germany and the large abundance of research data from past and current projects are primarily based on the work of key research institutions. These have been very pro-active in promoting the concept. Stakeholders farther up in the value chain are also interested in the idea in order to get a local sustainable product for their markets.
Offshore Wind Industry: The offshore wind industry as a whole has a low interest in multi-use of any kind unless there are clear added values and no risks involved. Certain key companies and

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associations, however, are interested in multi-use as a future use concept and have been partners in past research projects.

Cross-sector: Regulatory bodies are open to additional ocean uses like aquaculture as well as its connection with offshore wind energy as a multi-use. Regulators have been open to inquiries as well as project participation.

OVERALL ATTITUDE TOWARDS MU:

Aquaculture Industry: There is no offshore aquaculture industry active in the German North Sea EEZ as of yet. The key research actors in the aquaculture community in Germany, however, have a positive attitude towards multi-use and are acting as driving forces behind the development of this combination.

Offshore Wind Industry: The overall attitude of the offshore wind industry in regards to multi-use in any use combination is cautious. Under the German MSP for the EEZ, they have priority rights over other users inside their assigned priority areas. These protect their construction, operation and maintenance activities from other users. Most stakeholders see no need to jeopardize the security these rights guarantee them. These opposed actors possess an absolute veto-right against all activities inside their priority areas and use it to impose barriers. Some key stakeholders in the industry, however, are open to alternative use concepts and have participated in past projects in order to identify the approaches.

Cross-sector: Regulatory bodies are open to additional ocean uses like aquaculture as well as its connection with offshore wind energy as a multi-use. Regulators have been open to inquiries as well as project participation.

GEOGRAPHICAL SCALE AT WHICH CERTAIN STAKEHOLDER HAS THE POWER:

Aquaculture Industry: The identified key stakeholders are associations and research institutions. These operate on a national to international level. The individual members of associations from the commercial side, however, operate mostly on a regional and national level due their small scale of operations.

Offshore Wind Industry: Key offshore wind stakeholders, whether planners or operators, are almost exclusively part of multi-national energy providers with a sea basin or EU perspective.

Cross-sector: Relevant cross-sector authorities for this multi-use combination operate on the regional to national level.

ORGANISATION OF STAKEHOLDERS:

Aquaculture Industry: There is no offshore aquaculture industry active in the German North Sea EEZ as of yet. Germany’s aquaculture sector is made up of a number of research institutions from public and private research institutions to universities as well as companies focusing on land-based pond or recirculation aquaculture systems (RAS). Most of these individual companies and institutions are members of a sector wide association, the Federal Aquaculture Association (BVAQ). This association acts as a voice for the interests of the German aquaculture sector as well as a competency cluster for its members.

Offshore Wind Industry: The offshore wind industry is dominated by a low number of mostly multi-national energy corporations. They jointly support multiple associations and lobby groups to advance their interests.

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Cross-sector: Cross-sector authorities are organised at the federal-state (coastal states) and federal level.

TYPE OF POWER:

Aquaculture Industry: There is no offshore aquaculture industry active in the German North Sea EEZ as of yet. The only power which key actors from the research sector can exert is to influence decision makers. This is achieved by providing scientifically solid advice based on past and present research projects and communicating it the key decision makers.

Offshore Wind Industry: The offshore wind industry has greater influencing power than the second user, aquaculture in this case, due to their larger operations. The lead corporations are multi-national companies operating at a sea basin or EU wide level and provide thousands of high paid jobs in the technology sector. Furthermore, they have special absolute rights within their assigned priority areas over other uses and users.

Cross-sector: Relevant cross-sector authorities have direct power to control and make decisions within their mandated purview. They are immediately responsible to apply regulations and manage their jurisdiction accordingly. Apart from that they have the power to directly influence the decision making process.

LEVEL OF POWER:

Aquaculture Industry: The power of key aquaculture stakeholders to influence can be rated as low since there is no current large commercial interests backing their interests.

Offshore Wind Industry: The offshore wind industry has a larger influencing power than the second user, aquaculture in this case, due to their larger operations. The lead corporations are multi-national companies operating at a sea basin or EU wide level and provide thousands of high paid jobs in the technology sector.

Cross-sector: The power of the cross-sector authorities is strong as it is absolute within their mandated purview. They need to be included in any communication process regarding multi-use.

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Table 8 Summary of Stakeholders broad attributes in regards to multi-use.

Stakeholder Sectors	Attribute 1: Overall interest in MU	Attribute 2: Overall attitude towards MU	Attribute 3: Geographic scale of power	Attribute 4: Organisation of stakeholders	Attribute 5: Type of power	Attribute 6: Level of Power
Aquaculture	proactive	positive - driving forces	local-regional	couple of individual organisations	power to influence directly	low
Fisheries	proactive	positive - driving forces	national	strong clustering	power to influence directly	low
Offshore Wind	reactive	negative-but can positively influence barriers	national	strong clustering	power to influence directly	strong
Cross-sector	reactive	neutral/undecided	national	monopoly of one organisation	power to control and make decisions	strong

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8. CONCLUSIONS AND RECOMMENDATION FROM THE CASE STUDY TO THE ACTION PLAN

Multi-use combinations in the German North Sea EEZ are in various stages of development, mainly used in pilot scales for scientific purposes, however, none are in operation at this time. The combination of fisheries (either active or passive gear) and offshore wind energy is closest to realisation since both user groups are already established in the area. The combination of aquaculture and offshore wind energy is further removed from realisation but benefits from a larger cluster of know-how in the German and international research sector. Despite identifying other potential future multi-uses, these two scenarios offer the most promise in the immediate future. All stakeholders approached over the course of this case study were aware of the multi-use concept and open to discussion and cooperation. This is largely based on the long history of German multi-use projects with stakeholder participation in the area as well as the choosing of key stakeholders that represent their sector. Strategic German MSP documents recognise the potential that multi-use (i. e. offshore aquaculture in combination with offshore wind generation) has to offer, but the multi-use concept is still only an option open to the primary user in an assigned priority area. The main priorities to further develop the two primary combinations as well as any future combinations is to institute an open and direct dialogue between key stakeholders (i. e. users and regulators) to exchange the best available information and technology on all aspects of the combination. This will serve to alleviate security concerns and showcase added values for all involved stakeholders.
The specific steps proposed after analysis of this case study per combination are as follow:

For the combination of Offshore Wind Energy Generation & Fisheries:

(1) Clear and open communication between both user groups and regulators to communicate added values as well as share best available knowledge to address safety concerns on all sides.
(2) Cross-border exchange with regulators of bordering countries where this combination exists already (i. e. UK, DK) to find commonalities and streamline management approaches.
(3) Addressing all safety concerns regarding possible damages by fishing vessels and techniques to the OWF structures and cables in in-situ experiments and consequently develop management strategies and technologies to minimise those risks.

Additionally, though the current regulatory framework grants special considerations to fishermen as users, these consideration have to be turned into rights, given that valid safety concerns are addressed.

For the combination of Offshore Wind Energy Generation & Marine Aquaculture:

(1) Addressing the lack of a functioning full scale pilot facility (Technology Readiness Level 8) to showcase the combination. Though this pilot project needs to have an emphasis on safety concerns, environmental compatibility, integration of operations as well as economics, it needs to take an overall integrated approach and also address aspects such as relationships between users and risk insurance.
(2) Facilitating clear and open communication between all involved stakeholders to promote the sharing of all available information to address safety as well as environmental concerns.

Additionally, secondary users in a multi-use scenario need a legislated claim inside the OWF priority areas if their use has been proven to not be detrimental to the primary user, the environment or overall safety of operations and shipping.

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ACKNOWLEDGMENTS

This work, as well as all future multi-use developments, would not have been possible without the decades of research dedicated to advancing our knowledge of multi-use in the German North Sea by many scientists. Many of those same scientist helped in the critical review of all steps of this work. Lastly, all this work and the progress being made rests on the shoulders of the cooperation of local stakeholders interested in advancing novel ocean use concepts and engaging in discussions as well as providing invaluable insights and information.

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APPENDIX 1 – SCORED DABI SHEET

Overall DABI (driver, added values, barriers and impacts) scoring tables with scoring results from four stakeholder interviews.

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Fisheries Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
DRIVERS						
Category D.1 - Policy drivers						
Factor D.1.1 Fisheries is being awarded special considerations by the German MSP inside the priority areas for Offshore Wind Farms	-	-	-	-	-	
Average						-
Category D.2 - Relation with other uses						
Factor D.2.1 Expansion of new uses into the available area requires spatial efficiency to maintain livelihoods	-	2,5	2,0	3,0	2,5	
Average		**2,5**	**2,0**	**3,0**		2,5
Category D.3 - Economic drivers						
Factor D.3.1 Expansion of offshore wind power generation threatens livelihood of fisheries without multi-use development	-	-	-	-	-	
Average						-
Category D.4 - Societal drivers						
Category D.5 - Evironmental Drivers						
Factor D.5.1 Wind Turbines act as Fish attracting devices due to the special ecosystem their foundations offer, increasing the available biomass in their immediate surroundings and creating valuable fishing grounds	-	-	-	-	-	
Average						-

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Fisheries Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
BARRIERS						
Category B.1 - Legal barriers						
Category B.2 - Administrative barriers						
Factor B.2.1 Integration into existing Health and Safety Concepts of operational OWFs is too complex and would currently have to be solved on a case by case basis	-	-1,0	-	-	-0,5	
Average		**-1,0**				-1,0
Category B.3 - Barriers related with economic availability / risk						
Factor B.3.1 Insurance against possible damages to OWFs is prohibitively high for small scale fishing companies	-	-	-3,0	-	-3,0	
Average			**-3,0**			-3,0
Category B.4 - Barriers related with technical capacity						
Factor B.4.1 Determining liability in case of accidents and damage to offshore wind turbines can proof difficult and might require specialised surveillance equipment	-	0,0	0,0	0,0	0,0	
Factor B.4.1 Certain fishing methods (i.e. dredging) might damage cables connecting turbines (missing data for different depths and methods, based on precautionary principle)	-	-	-	-	-	
Average		**0,0**	**0,0**	**0,0**		0,0
Category B.5 - Barriers related with social factors						
Category B.6 - Barriers related with environmental factors						

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Fisheries Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
ADDED VALUES						
Category V.1 - Administrative added values						
Factor V.1.1 Co-location with Fisheries can ease obtaining an SLO (societal license to operate) for Wind Farm developers and operators	-	1,0	2,0	1,5	1,5	
Average		**1,0**	**2,0**	**1,5**		1,5
Category V.2 - Societal added values						
Factor V.2.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	-	3,0	-	-	3,0	
Average		**3,0**				3,0
Category V.3 - Environmental added values						
Factor V.3.1 No decrease in the level of production from well managed German (and European) fisheries will lead to less imports from less well managed fishing areas across the world and not increase overfishing as well as the CO2 footprint of consumed fisheries products	-	-	1,0	-	1,0	
Average			**1,0**			1,0
Category V.4 - Better ensurance policy and risk management						
Category V.5 - Technical added values						

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Fisheries Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
NEGATIVE IMPACTS						
Category I.1 - Economic impacts						
Category I.2. - Social impacts						
Category I.3 - Environmental impacts						
Factor I.3.1 Allowing fishing inside OWFs reduces the size of the current de-facto protected areas around installations (potentially increases shipping noise, fishing pressure, pressure on benthic ecosystem, etc.)		-2,0			-2,0	
Average		**-2**				-2,0
Category I.4 - Technical impacts						

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Combination: Offshore Wind & Aquaculture Country: Germany	Interviewee 1 *no scoring Score	Interviewee 2 Score	Interviewee 3 Score	Interviewee 4 Score	Factor average for all stakeholders	Category average (average of all factors averaged for all stakeholders)
DRIVERS						
Category D.1 - Policy drivers						
Factor D.1.1 Expansion of new uses into the available area requires spatial efficiency to allow future growth of additional uses	-	2,5	2,0	3,0	2,5	
Average		**2,5**	**2,0**	**3,0**		2,5
Category D.2 - Relation with other uses						
Factor D.2.1 German MSP urges connection of marine aquaculture and other offshore uses in order to benefit from synergistic effects	-	-	-	-	-	
Average						-
Category D.3 - Economic drivers						
Factor D.3.1 Increased economic potential for both users through cooperation's and sharing of resources	-	-	-	-	-	
Average						-
Category D.4 - Societal drivers						
Category D.5 - Evironmental Drivers						

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Combination: Offshore Wind & Aquaculture Country: Germany	Score	Score	Score	Score	Factor average for all stakeholders	Category average (average of all factors averaged for all stakeholders)
BARRIERS						
Category B.1 - Legal barriers						
Factor B.1.1 Any activity inside OWF must not hinder normal operations, maintenance or navigational safety inside the priority area	-	-	-	-	-	
Average						0,0
Category B.2 - Administrative barriers						
Factor B.2.1 Licensing for multiple uses is conducted separately and offers potential for simplifications	-	-1,0	-	-	-1,0	
Average		**-1,0**				-
Category B.3 - Barriers related with economic availability / risk						
Factor B.3.1 Moving aquaculture offshore requires special engineering solutions and makes day-to-day operations more expensive	-	-2,0	-	-	-2,0	
Factor B.3.2 Insurance against possible damages to OWFs is prohibitively high for small scale fishing companies	-	-	-3,0	-	-3,0	
Average		**-2,0**	**-3,0**			-2,5

The table continues in the next page

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Category B.4 - Barriers related with technical capacity						
Factor B.4.1 Connection of aquaculture systems to existing OWFs is not possible unless it was designed for the increased load	-	-3,0	-3,0	-	-3,0	
Factor B.4.2 Operations within OWFs would require a degree of integration into the Health & Safety Concept of the operator which is often not easily accessible	-	-	-	-	-	
Average		**-3,0**	**-3,0**			-3,0
Category B.5 - Barriers related with social factors						
Category B.6 - Barriers related with environmental factors						
Factor B.6.1 Opposition to aquaculture (whether fed, extractive or IMTA) in German waters	-	-	-	-	-	
Average						-

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Aquaculture Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
NEGATIVE IMPACTS						
Category I.1 - Economic impacts						
Category I.2. - Social impacts						
Category I.3 - Environmental impacts						
Factor I.3.1 If aquaculture is not well managed according to BMP (best management practice), BAT (best available technology) and BEP (best environmental practice), it can have negative impacts on the marine environment (e.g. eutrophication, spread of disease or impact of escapees on natural populations)	-	-3,0	0,0	-	-1,5	
Average		**-3**	**0**			-1,5
Category I.4 - Technical impacts						

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	Interviewee 1 *no scoring	Interviewee 2	Interviewee 3	Interviewee 4		
Combination: Offshore Wind & Aquaculture Country: Germany	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
ADDED VALUES						
Category V.1 - Administrative added values						
Factor V.1.1 Co-location with Fisheries can ease obtaining an SLO (societal license to operate) for Wind Farm developers and operators	-	1,0	2,0	1,5	1,5	
Average		**1,0**	**2,0**	**1,5**		1,5
Category V.2 - Economic added values						
Factor V.2.1 Possible lowering of operational costs for all involved actors through sharing of resources (e.g. vessels, ports, etc.) and integration and cost sharing of health and safety concepts	-	3,0	0,0	-	1,5	
Average		**3,0**	**0,0**			1,5
Category V.3 - Environmental added values						
Factor V.3.1 Spatial efficiency will make it possible to reserve areas for new ocean uses that might not be apparent yet and lead to an overall decrease of the human geographic footprint	-	3,0	-	-	3,0	
Average		**3,0**				3,0
Category V.4 - Better ensurance policy and risk management						
Category V.5 - Technical added values						

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APPENDIX 2 – LISTO OF PROJECTS

List of projects (national and international) assessed during the desk study phase of this case study. (in alphabetical order, no-desk top-feasibility studies, last update 9th February 2017)

EU-funded projects				
No.	**Project**	**Uses**	**Co-Uses**	**Reference**
(1)	**COEXIST** Project ID 245178	Fisheries and aquaculture	Other coastal activities (stakeholder)	Cordis Final report summary http://cordis.europa.eu/result/rcn/140612_en.html Soma K, Ramos J, Bergh Ø, Schulze T, van Oostenbrugge H, van Duijn AP, Kopke K, Stelzenmüller V, Grati F, Mäkinen T, Stenberg C, Buisman E (2013) The "mapping out" approach: effectiveness of marine spatial management options in European coastal waters. ICES Journal of Marine Science; doi:10.1093/icesjms/fst193, 29 December 2013, Fanny Douvere
(2)	**H2Ocean** Project ID 288145	Wind and Wave energy	Aquaculture, Hydrogen (stored and shipped to shore as green energy carrier)	Cordis Final report summary http://cordis.europa.eu/result/rcn/177009_en.html
(3)	**MARIBE** (Marine Investment for the Blue Economy - Baltic, North Sea, Atlantic, Caribbean, Mediterranean) Project ID 652629 (collected results from all other finished EU multi-use projects)	Caribbean: Aquaculture	Tourism, Wave energy, Desalination	Cordis http://cordis.europa.eu/result/rcn/185673_en.html Maribe final booklet http://maribe.eu/wp-content/uploads/2016/08/maribe-booklet-final.pdf
		North Sea: Aquaculture	Oil & Gas, Wave energy, Tourism	
		North Sea: Seabed mining	Fisheries,	
		North Sea: Oil & Gas	Floating wind energy	
		Atlantic: Tidal lagoon	Tourism, Aquaculture	
		Atlantic: Offshore wind	Desalination, Oil & Gas	
		Atlantic: Aquaculture	Biotechnology, Blue life science	
		Baltic: Aquaculture	Wave energy, Oil & Gas, Tourism	
		Baltic: Seabed Mining	Fisheries	

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EU-funded projects				
		Mediterranean: Offshore wind	Fisheries	
		Mediterranean: Aquaculture	Tourism	
(4)	**MERMAID** (Baltic, North Sea, Atlantic Mediterranean, Lead: DTU) Project ID 288710 **(Statoil)**	Atlantic: Offshore wind and wave energy	Maritime transport,	Pirlet H, Claus S, Copejans E, Damgaard Christensen E, Guanche García R, Møhlenberg F, Rappé K, Schouten JJ, Zanuttigh B (2014) The Mermaid project - Innovative Multi-Purpose Offshore Platforms. Flanders Marine Institute (VLIZ): Ostend. ISBN 978-90-820731-9-5. 20 pp.
		Mediterranean: Wave energy	Leisure , Aquaculture , Maritime transportation	
		North Sea: Wind energy	Aquaculture (seaweed and shellfish), Tourism	
		Baltic: Wind farm	Passive Fisheries, Aquaculture (fish and seaweed)	
(5)	**MUSES** (Stakeholder, no platform, Lead: Marine Scotland) Project ID 727451 **(AWI)**	Fisheries, Wind energy	Aquaculture, Wave energy, Maritime transport, Tourism	Cordis http://cordis.europa.eu/project/rcn/205970_en.html
(6)	**ORECCA** (Offshore Renewable Energy Conversion platforms – Coordination Action) Project ID 241421	Offshore Renewables	Aquaculture (biomass and fishes), Monitoring of the sea environment (marine mammals, fish and bird life)	
(7)	**TROPOS** (Mediterranean, Tropic, Sub-tropic, Lead: PLOCAN) Project ID 288192 **(PLOCAN, AWI)**	maritime transport (offshore port and base of logistic service for energy sector)	Fisheries (service station, storage), Aquaculture (fish), Energy (solar and ocean wave), Leisure activities (floating hotel, underwater observation facility, scientific tourism, diving base, yachting services)	Quevedo E, Carton M, Delory E, Castro A, Hernandez J, Llinas O, De Lara J, Papandroulakis N, Anastasiadis P, Bard J, Jeffrey H, Ingram D, Wesnigk J (2013) Multi-use offshore platform configurations in the scope of the FP7 TROPOS Project in: OCEANS - Bergen, 2013 MTS/IEEE, 10-14 June 2013 http://www.tropospIatform.eu
(8)	**MARINA Platform** Project ID 241402	Wind Energy	Wave Energy	Cordis http://cordis.europa.eu/project/rcn/93425_en.html

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National funded projects				
No.	**Project**	**Use**	**Co-Use**	**Reference**
(1)	**AquaLast** (Germany – Lead: AWI; University of Applied Sciences Bremerhaven, Fraunhofer, Weswerwind, TKB) **(AWI)**	Offshore Wind Energy	Aquaculture (loading on offshore support structures, such as wind turbine foundations, caused by mussel longlines)	Buck BH, Zielinski O, Assheuer A, Wiemann K, Hamm C, Kassen D (2006) *AquaLast* - Technische Umsetzung von extensiven Marikulturanlagen in Windparks: Betrachtung der mechanischen Lasten, Endbericht des Projektes FV 174, gefördert durch den SBUV des Landes Bremen, 57 pp.
(2)	**Biological and technical feasibility study of marine aquaculture in the Thorthonbank area, Belgium: Co-use of space with offshore wind farms** (Belgium - University of Ghent, SINTEF Ocean) **(SINTEF Ocean)**	Offshore Wind Energy	Aquaculture (farming of blue mussel)	Confidential report
(3)	**Coastal Futures** (Germany – Lead: University of Kiel; AWI, GKSS) **(AWI)**	Offshore Wind Energy	Aquaculture (integrated coastal zone management for the integration of aquaculture into wind farm areas)	Michler-Cieluch T (2009) Co-Management Processes in Integrated Coastal Management - The Case of Integrating Marine Aquaculture in Offshore Wind Farms. University of Hamburg, Department of Integrative Geography.
(4)	**Flandres Queen Mussel (FIOV)** (Belgium - Stichting voor Duurzame Visserijontwikkeling -SDVO, ILVO)	Offshore Wind Energy	Aquaculture (development of floating buoys with mussel ropes for spat collection)	Van Nieuwenhove K (2008) FIOV-project: Studie naar de commercialisering van de Belgische off-shore hangmosselcultuur. WP3. Uitbreiding van schelpdierproductiegebieden. Insti-tuut voor Landbouw- en Visserijonderzoek (Aquacultuur) 46p.
(5)	**Gulf of Mexico OOA** (USA – University of Texas)	Offshore Oil Platforms	Aquaculture (multi-use of offshore fish cultivation in combination with offshore Oil & Gas)	Miget RJ (1994) The Development of Marine Fish Cage Culture in Association with Offshore Oil Rigs. In: KL Main, C Rosenfeld (Eds.), Culture of High Value Marine Fishes in Asia and the United States. Proceedings of a Workshop in Honolulu, Hawaii, August 8-12, 1994. The Oceanic Institute. pp. 241-248 Wilson CA, Stanley DR (1998) Constraints of Operating on Petroleum Platforms as it relates to Mariculture: Lessons from Research. In: RR Stickney

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EU-funded projects				
				(Ed.), Joining Forces With Industry - Open Ocean Aquaculture. Proceedings of the 3rd Annual International Conference, May 10-15, Corpus Christi, Texas. TAMU-SG-99-103, Corpus Christi, Texas Sea Grant College Program. pp. 60
(6)	**Integrate the offshore wind technology with aquaculture – development of fish farm equipment for offshore conditions** (Norway - Statoil, SINTEF Ocean and Lerøy Seafood Group) **(Statoil, SINTEF Ocean)**	Offshore Wind Energy	Aquaculture (fish farming of salmon)	http://www.regionaleforskningsfond.no/prognett-vestlandet/Prosjekt_2013/1253987862764
(7)	**KOREA Co-Location** (South Korea – Lead: Korea Electric Power Cooperation Research Institute (KEPCO); Korean Institute of Ocean Science and Technology - KIOST) **(AWI)**	Offshore Wind Energy	Fisheries (passive fisheries), Aquaculture (seaweed production for biomethane and bioproducts in wind farms)	KEPCO, KIOST (2016). Co-location of fisheries with offshore wind farm: An overview of research carried out in KEPCO Research Institute & KIOST. Korea Electric Power Cooperation – Research Institure (KEPCO) and Korean Institute of Ocean Science and Technology (KIOST).
(8)	**Mosselkweek in Belgische windmolenparken** – Mussel production within Belgium Wind Farms (Belgium – Lead: University of Ghent; ILVO, AWI, SINTEF, et al.) **(AWI, SINTEF)**	Aquaculture	Wind energy, Maritime energy	Pers. Comment Dr. Nancy Nevejan (Ghent Universitzy, Belgium)
(9)	**MytiFit** (Germany – Lead: AWI; Engel Netze, LAVES) **(AWI)**	Offshore Wind Energy	Aquaculture (mussel fitness, infestation of parasites, and selection of hard substrates for multi-use)	Buck BH, Köhler A, Brenner M, Stede M, Engel M (2007) MytiFit: Use of the Offshore Wind Farm Site „Nordergründe" for the multi-use of blue mussels: fitness, infestation of parasites, and selection of hard substrates Funding Programme Applied Environmental Research (Angewandte Umweltforschung - AUF), Senate for Environment, Construction, Traffic and Europe, Bremen. Final Report FV 168, 32 pp.

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(10)	**NutriMat** (Germany – Lead: IMARE; Greim Fish Consulting, AWI, University of Applied Science Bremerhaven, WeserWind, Louis Schoppenhauer GmbH & Co. KG) **(AWI)**	Offshore Wind Energy	Aquaculture (use of fouling organisms of offshore platforms for fish feed in land-based aquaculture)	Weiss M, Buck BH (accepted) *Blue mussel* (Mytilus edulis) *meat as a partial fish meal replacement for the diet in turbot aquaculture*. Journal of Applied Ichthyology.
(11)	**Nysted Sea Wind Farm Mussels** (Belgium – DTU)	Offshore Wind Energy	Aquaculture (investigation on the possibility to multi-use for longline mussel farming)	Christensen HT, Christoffersen M, Dolmer P, Stenberg C, Kristensen PS (2009) Assessment of possibilities for line cultivation of mussels in Nysted Sea Wind Farm. Project report DTU Aqua.
(12)	**Ocean Forest** (Norway – Leroy Seafood Group, Bellona Foundation)	Aquaculture (multi-trophic) Energy	Aquaculture (bio-mass production for energy generation)	http://bellona.org/projects/ocean-forest
(13)	**Offshore-Aquaculture** (Germany – Lead: AWI; Terramare) **(AWI)**	Offshore Wind Energy	Aquaculture (investigations of the settlement and growth of bivalves and macroalgae in the German Bight to test its feasibility for offshore multi-use)	Buck BH, Pogoda P, Grote B, Krause G, Wever L, Mochtak A, Czybulka D (2017) Case Study German Bight: Pioneer Projects of Aquaculture-Wind Farm Multi-Uses. In: Buck BH, Langan R (eds) Aquaculture perspective of multi-use sites in the open ocean: The untapped potential for marine resources in the Anthropocene. ISBN: 978-3-319-51157-3
(14)	**Offshore Site Selection** (Germany – Lead: AWI; Thünen, University of Rostock, Kutterfisch, WindMW, Deutscher Fischereiverband, Skretting) **(AWI, WindMW)**	Offshore Wind Energy	Aquaculture (offshore site selection for IMTA in co-use of offshore wind farms)	Gimpel A, Stelzenmüller V, Grote B, Núñez-Riboni I, Buck BH, Pogoda B, Floeter J, Temming A (2015) Evaluating the co-use of offshore wind farms and aquaculture in the German EEZ - a GIS modelling approach. Marine Policy 55: 102-115. Pogoda B, Grote B, Buck BH (2016) „Offshore-Site-Selection für die nachhaltige und multifunktionale Nutzung von Meeresarealen in stark genutzten Meeren am Beispiel der Nordsee - Teilprojekt 1“. Gefördert durch die Bundesanstalt für Landwirtschaft und Ernährung. Förderkennzeichen: 2817300910 , 97 pp. Stelzenmüller V, Diekmann R, Bastardie F, Schulze T, Berkenhagen J, Kloppmann M, Krause G, Pogoda B, Buck BH, Kraus G (2016) Co-location of

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				passive gear fisheries in offshore wind farms in the German EEZ of the North Sea: A first socio-economic scoping. Journal of Environmental Management 183(3): 794-805.
(15)	**Open Ocean Use (OOMU)** (Germany – Lead: IMARE; EWE, University of Hannover, Thünen Institute, Bard Engineering, Kutterfisch, Frosta, AWI) **(AWI)**	Offshore Wind Energy	Aquaculture (investigation on integrating an offshore fish cage into tripile foundation)	Buck BH, Dubois J, Ebeling MW, Franz B, Goseberg N, Hundt M, Schaumann P, Schlurmann T, Schmidt J, Vollstedt B, Wever L (2012) Mulitple use and co-management offshore structures: Marine aquaculture and offshore wind farms. Open Ocean Multi-Use (OOMU) Final Report, Ministry for Environment, Nature Conservation, and Nuclear Safety. 256 pp.
(16)	**Roter Sand Project** (Germany – Lead: AWI) **(AWI)**	Offshore Wind Energy	Aquaculture (development of system design for the use of offshore environments for the cultivation of species for aquaculture and bioextraction)	Buck BH, Pogoda P, Grote B, Krause G, Wever L, Mochtak A, Czybulka D (2017) Case Study German Bight: Pioneer Projects of Aquaculture-Wind Farm Multi-Uses. In: Buck BH, Langan R (eds) Aquaculture perspective of multi-use sites in the open ocean: The untapped potential for marine resources in the Anthropocene. ISBN: 978-3-319-51157-3 Buck BH (2007) Experimental trials on the feasibility of offshore seed production of the mussel *Mytilus edulis* in the German Bight: Installation, technical requirements and environmental conditions. Helgoland Marine Research 61: 87-101.
(17)	**SOMOS** – Safe production Of Marine plants and use of Ocean Space (The Netherlands – Lead: Wageningen University; TNO) **(AWI)**	Offshore Renewable Energy	Aquaculture (Seaweed farming)	https://www.wur.nl/en/project/SOMOS.htm
(18)	**Stichting Noordzeeboerderij** (The Netherlands – Hortimare, Schuttelaar and Partners)	Offshore Wind Energy	Aquaculture (development of a seaweed technology and mass algal production)	Hortimare (2016) Propagating Seaweed for a Sustainable Future. http://www.hortimare.com/
(19)	**WINSEAFUEL** (France - French National	Offshore Wind Energy	Aquaculture (seaweed mass production for	Lasserre T, Delgenès JP (2012) WindSeaFuel: Production de macro-algues pour une valorisation en

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	Research Agency)		biomethane and bioproducts in wind farms)	méthane et autres bioproduits. ANR Bioénergies 2009 Poster, ANR-09-BIOE-05, Label pôle, DERBI-TRIMATEC.

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APPENDIX 3 – INTERVIEW SHEET

Interview sheets used during in-person semi-structured interviews with key stakeholders.

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Drivers- Page 1							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, +1, +2, +3)
OW-all	Other Uses in OWFs could compensate the reduction of the available area, due to the establishment of Marine Parks (spatial efficiency)						
OW-all	Laws/regulations now require that wind farm developers must consider co-location/multi-use as part of their application for a permit to develop a new wind farm. (The German spatial plan for the German Exclusive Economic Zone explicitly recommends combinations among facilities for mariculture and existing installations such as the foundations of offshore wind turbines.)						

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Added Values - Page 1							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, +1, +2, +3)
OW-all	Co-location enhances the social acceptance of Offshore Wind (and (SLO) • Money flows into local communities • MU-represents a more sustainable approach						
OW-AQ	Logistics optimization – reduced operational costs in case of sharing of infrastructure						

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Added Values - Page 2							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, +1, +2, +3)
OW-Fisheries	More production of European capture fisheries means less pressure on less regulated fishing areas - Fishery in European waters adheres to better management practices and produces a more sustainable product						

Barriers - Page 1							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, -1, -2, -3)
OW-AQ	Technical challenges due to greater load in case of physical connection of the two uses						

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OW-AQ	Uncertain profitability due to higher economic costs for operating in an offshore environment (for aquaculture)						

Barriers - Page 2							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, -1, -2, -3)
OW-all	Insurance against damages to high cost OW installations is difficult and expensive						
OW-all	Licensing for multiple uses too complex						

Barriers - Page 3							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, -1, -2, -3)
OW-Fish	Liability / Assigning blame in case of accidents can be difficult						

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OW-AQ	Offshore environment provides high demands on infrastructures and difficulty of access to service aquaculture installations						

Barriers – Page 4							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, -1, -2, -3)
OW-AQ	Societal opposition to Aquaculture in Germany (NIMBY)						

Impacts - Page 1							
Combination	Factor	Agree or Disagree	Geographical Scale (i.e. local, national, EU, other)	Actors	Power (i.e. power to control, influence, none, other)	At what scale does this actor hold this power? Local, national	Score (NK, 0, -1, -2, -3)
OW-AQ	Possible negative impacts of aquaculture on the surrounding ecosystem						

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OW-Fisheries	Reduction of de-facto protected areas around OW farms						

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